Final Peer Review Summary Report

External Peer Review of Kuipers et al. 2006 (*Comparison of Predicted and Actual Water Quality at Hardrock Mines*)

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Peer Reviewers:

David A. Atkins, M.S.
Robert Kleinmann, Ph.D.
Dina L. Lopez, Ph.D.
Christian Wolkersdorfer, Ph.D.

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Prepared for:
U.S. Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
1200 Pennsylvania Avenue, NW (8623-P)
Washington, DC 20460

Prepared by:
Versar, Inc.
6850 Versar Center
Springfield, VA 22151

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I. INTRODUCTION

In May 2012, the U.S. Environmental Protection Agency (EPA) released a draft report entitled *An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska*. The purpose of this report was to put forth a prospective risk assessment of large-scale mining in the Bristol Bay watershed, focusing on a specific case study for a hypothetical but realistic mine scenario at the Pebble deposit. Specifically, the assessment examines how future large-scale mining may affect water quality, habitat, and salmon fisheries in the Bristol Bay watershed. During preparation of this draft assessment, EPA identified the following two reports developed by non-EPA scientists that contained information relevant to this topic, but were not included because they had not been peer-reviewed: *Comparison of Predicted and Actual Water Quality at Hardrock Mines* (Kuipers et al. 2006) and *U.S. Copper Porphyry Mines: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures and Water Collection and Treatment Failures* (Earthworks 2012).

The purpose of this letter peer review is to determine if the information contained in the Kuipers et al. 2006 report is of sufficient scientific quality and credibility to be incorporated into EPA's revised Bristol Bay report.

PEER REVIEWERS

David A. Atkins, M.S.
Watershed Environmental, LLC

Robert Kleinmann, Ph.D.
Independent Consultant

Dina L. Lopez, Ph.D.
Ohio University

Christian Wolkersdorfer, Ph.D.
International Mine Water Association

II. PEER REVIEW OF KUIPERS ET AL. 2006 REPORT

II.1 Charge to Reviewers

The report to be reviewed is *Comparison of Predicted and Actual Water Quality at Hardrock Mines* (Kuipers et al. 2006). This report evaluates the reliability of pre-mining water quality predictions at U.S. hardrock mining operations, and analyzes the most common causes of water quality impacts and prediction failures. Please provide detailed explanations for responses to the charge questions below.

Charge Questions:

1. Are the conclusions of the report well-supported by the evidence provided? Why or why not?

2. What are the strengths and weaknesses of the Kuipers et al. 2006 report, in terms of:

   a. Methodology?

   b. Results and conclusions?

3. Are there important limitations or uncertainties associated with applying results from the Kuipers et al. 2006 report to the EPA assessment? If so, what are they?

II.2 General Impressions

David A. Atkins

The report does an admirable job of identifying, evaluating, and synthesizing a lot of information (183 mines total, with 25 evaluated in detail). The sheer volume of information presented and the overly descriptive presentation style make the report difficult to digest. Much of the information presented in the main report may have been better relegated to an annex.

Most of the mines evaluated in detail had the National Environmental Policy Act (NEPA) permitting documents from the 1980s and 1990s. Characterization, modeling, and prediction have improved since then, so results of this analysis should be applied with caution. A prediction failure is defined as when actual results differ from predicted results. This is an overly conservative definition of failure given the many uncertainties associated with modeling natural systems. It would have been helpful to understand which predictions resulted in 'catastrophic' failures, or those failures that have long-term impacts that cannot be reasonably corrected or mitigated. The report also does not take into account the role of the regulatory agency in ensuring harm is minimized after the Environmental Impact Statement (EIS) is approved through permitting and compliance monitoring, as well as any contingency and bonding requirements.

The report highlights the need for characterization and modeling to identify critical project impacts and that mitigation strategies be developed with redundancy at multiple levels in an adaptive management strategy.

Robert Kleinmann

Kuipers et al. should be commended for the amount of data that they assembled and assessed. I was part of a team that looked at such data for the eastern U.S. surface coal mines back in the 1980s as part of a much narrower U.S. Bureau of Mines research effort. We focused only on overburden analysis procedures and the accuracy of the predictions, and only looked at mines within a relatively narrow window of time, compared to this study, though our conclusions were similarly damning. Our results led to a major change in how mining companies were required to assess overburden characteristics in some states, which subsequently greatly improved water quality predictions. Kuipers et al. took on a much greater task and apparently waded through many reams of environmental impact statements and their equivalents in search of data that could be used in this study and, in some cases, followed that up by contacting the appropriate regulatory agencies to obtain recent (at the time) water quality information. Some of the case studies that they cite are relatively weak in detail, but that is presumably due to limited information in the older files rather than superficial data extraction by the authors. Overall, I was impressed with the breadth of this study and surprised that I had not previously heard of it. I expect this is due to the way that it was published and the fact that it has not previously been peer-reviewed. I expect that it would have had a greater impact if it had been published in a more appropriate way.

The report is highly critical of the mining industry and the regulatory agencies that oversee it. Does it come across as biased? Perhaps slightly, in the nature of the information that it chooses to include and emphasize for each mine site (i.e., comparisons to drinking water standards are generally inappropriate for mine water discharges, except in the rare instance when the mining company is required to adhere to such standards); but in general, it attempts to report information without pointing fingers. After reading the report, it is clear that the hardrock mining companies, which were, after all, seeking permits to mine, were either optimistically or cynically emphasizing aspects that minimized likely adverse consequences. In addition, it is clear that the hardrock mining companies and perhaps the regulatory agencies overseeing them did not adequately emphasize environmental aspects during mine planning and mining operations.

Dina L. Lopez

I have reviewed the report entitled *Comparison of Predicted and Actual Water Quality at Hardrock Mines* by Kuipers et al. (2006) and found the report very interesting and well written. The authors present a thorough review of major metal mines in the U.S., with emphasis on mines that have presented EISs or Environmental Assessments (EAs) to comply with NEPA. The report has investigated those documents for the assessment of acid mine drainage and leaching potential and the factors that could produce environmental impacts to surface and groundwater quality (e.g., distance to surface and groundwater, geological and geochemical characterization), as well as the mitigation measurements and their predicted effectiveness. The predicted surface and groundwater chemistry has been compared with the observed values to determine the success of mitigation efforts and the reliability of the predicted studies. The methodology used in the report seems appropriate for the objectives, with some minor problems, as described below. The conclusions are well supported, especially in terms of the identification of the factors that determine when the operation of the mine could impact surface and groundwater and why the predictions failed in the majority of the cases.

Christian Wolkersdorfer

The report investigates in detail 25 case studies of the 183 major U.S. hardrock mines identified by Kuipers et al. and compares the predictive calculations of EISs with the real situation after mine closure.

Without having double-checked every single case, the data provided seem to be accurate and, without a doubt, the information – not the conclusions – they gathered is of great value for the mining business. To my knowledge, it is the first time such a comprehensive compilation of data was attempted, but several trials have been done before (Demchak et al. 2000 several sites; DeHay 2003 compared just one site; Werner et al. 2008 surface mine in Germany; and Brown 2010 for the U.S.).

Most of the information is presented in a clear way, though the standardized structure they are using throughout the report gets tiring after a while and sometimes the small differences in the tables are not easy to pick up. Sound statistical investigations are completely missing.

The conclusions they draw can only be used for the 25 case studies they investigated, as there is neither statistical proof that they represent all 183 major hardrock mines, nor can they be representative for future hardrock mines with more stringent environmental requirements than in the past.

II.3 Response to Charge Questions

Question 1. Are the conclusions of the report well-supported by the evidence provided? Why or why not?

David A. Atkins

First, I'll summarize the conclusions. The report notes that since 1975, 183 major hard-rock mines have operated in the US, with about half of these currently closed. 137 mines triggered NEPA action, and 71 had EIS documents available for review. The report reviewed information from these reports to determine the availability of water quality predictions and selected 25 mines with documentation available from the time period between 1979 and 2005 for more detailed review. The subset was selected for characteristics that had a similar distribution to those for the complete list of 183 mines, including location, commodity, mining methods, climate, proximity to water resources, and acid drainage and contaminant leaching potential. The analysis of NEPA documents included review of both potential (without mitigation) and predicted (with mitigation) water quality impacts. Generally, NEPA documentation showed no impacts for predicted water quality even if potential water quality impacts were identified because mitigation was typically modeled to eliminate any potential impacts. The report further notes that a mine with significant predicted impacts that are not mitigated would likely not be permitted.

The study found that although most of the 25 case-study mines predicted no impacts to surface water or groundwater quality after mitigation, for the majority of the mines evaluated in detail, impacts have occurred. This mismatch between prediction and actual water quality was deemed a failure, and failure modes were divided into geochemical, hydrologic, and engineering or mitigation failures. Of the 25 mines studies in detail, the report finds that 15 had exceedences of surface water standards and 17 had exceedences of groundwater standards. Nine had developed acid drainage.

The report further concludes that potential impacts presented in the NEPA documentation are better predictors of actual impacts than predicted impacts (with mitigation). Causes include the lack of adequate geochemical and hydrologic characterization that results in inappropriate design and associated mitigation failure. The report further concludes that the combination of the proximity to water resources and moderate to high acid drainage or contaminant leaching potential increases the risk of water quality impacts and is a good indicator of the potential for future impacts.

The conclusions as presented are generally supported. In many of the mines discussed in detail, characterization and modeling were inadequate and, consequently, mitigation measures were not always effective. However, it is possible in some instances that prediction errors are within the bounds of what is reasonable given the inherent uncertainty of modeling natural systems. It would have been helpful to understand which prediction 'failures' could be deemed catastrophic (e.g., resulted in significant errors in project or engineering design) vs. those that resulted in minor but correctable problems.

These conclusions may not be readily extrapolated to more recent mining projects as discussed in the answers to the next two questions. For example, characterization and modeling have improved over time and most mines permitted currently would be expected to have a more standardized and robust characterization and modeling approach.

Monitoring during operations, regulatory actions, and contingency in the event of unanticipated water quality problems were also not considered in the report.

Robert Kleinmann

In my opinion, the conclusions of the Kuipers et al. 2006 report (pp. 193-194) accurately reflected the results of their study. The predictive procedures and mitigative measures that had been followed at the various mine sites had generally been shown to have not worked well. I was pleased to see that the authors did not simply dwell on this; instead, they briefly discussed what was being done incorrectly and then, in many cases, briefly stated what the mining companies should focus on to improve the accuracy of their predictions. I wish the authors had been a little more explicit in their comments, as I believe they had the data to do so; but to some extent, they had already done this in the text and executive summary.

Dina L. Lopez

In general, we can say that the conclusions are well supported. The authors explore the possible reasons why the predicted chemistry and impacts after mitigation in mines often fail. The factors that they investigated are those that the majority of researchers have long suspected to be the cause for lack of success in the predictions and mitigation. However, it is good to finally have a report that explores in a quantitative manner those factors for specific mines that have available data. ***Within the limitations of the available data and the used methodology***, the conclusions are sound and well-supported. However, one problem with the report is the fact that the comparisons that they are making are with drinking water standards. A better comparison should be done with baseline data prior to the exploitation of the mine for surface as well as groundwater. It is clear that baseline data are probably not available in the majority of mines investigated and that is probably the reason why the authors decided to compare with drinking water standards. Another problem is the fact that the legal requirements for the content and extent of the EISs and EAs in each case or state (better by case because legal requirements change with time, and the EIs and EAs have been written at different times) are not presented. However, the authors were more interested in demonstrating how the predicted and actual impacts differed or were similar, or if exceedances were occurring. That purpose was accomplished with the developed methodology.

Christian Wolkersdorfer

The summary of results provided seems to indicate that environmentally friendly mining is impossible (Table 8.2). Yet, their summary table is based on a small subset of all major mines in the U.S. only. As I will show hereafter, they cannot prove that their subset is representative for all major U.S. mines. In addition, their summary table only describes old mines – where environmental requirements might have been less stringent than today.

Based on the 25 case studies, the authors conclude that regulatory review processes in the U.S. "should include an adequate analysis of baseline water quality, hydrological characterization and geochemical characterization and the full identification of appropriate mitigation and potential mitigation failures". This is not new, as it is already done now, and based on the improvement of technology and science, regulatory bodies constantly adapt their review process to the newest technology available.

This, from my point of view, is the most critical finding in their report: they identified potential weaknesses in past EIS processes and describe how they can be overcome in the future. An unreliable prediction in past EISs does not mean that future EISs will be unreliable as well because the mining industry also learned from failures. I know that much has been done in the mining industry and consulting companies to learn from the recommendations given in Kuipers et al. 2006 – and, of course, because they are interested in better predictions themselves.

Therefore, the conclusions drawn by Kuipers et al. are correct for the 25 mines they investigated in 2006, but they cannot be used to predict the outcome of future predicted water qualities during or after mining.

Question 2. What are the strengths and weaknesses of the Kuipers et al. 2006 report, in terms of:
a. Methodology?
b. Results and conclusions?

David A. Atkins

a. Methodology?

The huge task of identifying and compiling the information from 183 total mining projects and 25 mining projects in detail is commendable. Synthesizing all this information is unique to my knowledge and the synopses presented in Appendices A and B are thorough. The method correctly identifies three components that influence a prediction – geochemical, hydrologic, and engineering or mitigation – and further identifies fault modes for each component as follows:

- Geochemical:
  - Contaminant of concern (COC) identification and inaccurate prediction of concentrations
  - Lack of representative sampling
  - Lack of appropriate testing
  - Inaccurate assumptions

- Hydrologic:
  - Site water balance
  - Under-prediction of design storm magnitude
  - Over-prediction of dilution from mixing

- Engineering:
  - Inadequate mine planning features designed to collect impacted water and restrict movement, including under drains, liners, pump-back systems, treatment ponds, waste rock segregation or blending, etc.

The study considered a site a failure for prediction if any environmental assessment document produced a prediction that did not match measured water quality in receiving water bodies. This criterion may result in overestimating failure as follows:

- Multiple predictions did not seem to be accounted for to determine how frequently a particular site had a prediction that did not match measurements.

- The magnitude of prediction error was not considered.

- The ramifications of the prediction errors were not considered in depth. In other words, it would be helpful to know if the prediction error resulted in a catastrophic failure not easily remedied (e.g., the mine was not predicted to require perpetual treatment, but now does) or failed to identify an exceedence in a monitoring location that is relatively easily mitigated (e.g., temporary seepage that results in an exceedence, but can be mitigated with a short-term pump back system).

b. Results and conclusions?

The report correctly identifies the uncertainty in model prediction and the potentially serious consequences of not getting predictions right (e.g., perpetual treatment). However, there are several factors that are not fully considered in the report that deserve more analysis when determining the utility of model prediction:

- Even if a model is not accurate in predicting water quality, it may be functionally correct in identifying areas or contaminants of concern and, thus, useful for determining best management practices.
- There is no discussion of the inherent difficulty of predictive modeling and how results should be interpreted (i.e., with caution and with liberal use of contingencies).
- There is no distinction between what is a reasonable prediction error, with distinction between errors that may have limited impact on the environment vs. catastrophic failures.

Further, the report does not take into consideration monitoring during operations and associated regulatory action that may include further mitigation, contingency plans, and bonding as a way of responding in the event of a prediction error. The study does seem to show that characterization approaches and prediction ability have improved over time.

Robert Kleinmann

a. Methodology?

Strengths: The researchers undertook a major task that had not previously been attempted and followed it through, which took a great dedication of effort. It appears that the information that they presented in their case studies, though sometimes limited by its nature, was accurately presented and analyzed. Moreover, the report, though somewhat formulaic, was generally well-written. The case studies were chosen with care and it is clear that the authors actually read all of the various reports that they referred to in their analysis. I was impressed with their thoroughness.

Weaknesses: There are some typos and proofreading errors and an occasional inappropriate word choice (e.g., surface water when they clearly meant ground water), but I think it is very well-written for a report distributed free of charge on the internet. I would have preferred to have seen its conclusions backed up by more thorough use of the technical literature (it has only one page of reference citations, some of which were relatively old at the time this report was prepared and some of which themselves have only been published online). Had the authors included citations for all of the individual reports that they extracted data from, the reference list would have been at least 10 pages long.

b. Results and conclusions?

Strengths: As indicated elsewhere, the results and conclusions at the back of the report are brief, but accurately reflect the findings of the study.

Weaknesses: The results of this report are summarized on one page, while the conclusions and recommendations are only two pages long. Clearly, the authors could have discussed the overall results in greater detail. They did so, in the text for each case study, so why not expand their discussion of their overall results? Of course, it is a little late to state this, six years after the fact.

On page 85 of the report, Kuipers et al. stated: "After 1990, many of the mines were conducting combinations of kinetic testing and static or short-term leach testing. EISs performed after about 1990 should have more reliable information on water quality impact potential than those with EISs completed before this time." Based on my own experience, this statement made sense, so using the data I could glean from this study, I attempted to see if this is true, and indeed, it appeared that it is. I think this conclusion should have been tested by the authors of this report, since they had the data to do so, and incorporated in the report's conclusions since it provides a clear sign of progress and a direction that other mining companies can follow to improve their predictive procedures.

Dina L. Lopez

a. Methodology?

The strength of the report is the extensive database that they have investigated (71 mines for predictions and 25 for comparison of predictions and observed impacts). Considering the complexity of the problem with multiple states, multiple regulations, and the difficulties in obtaining the reports and the data, I can see the magnitude of their work. The authors have done a careful job identifying the parameters and summarizing the content of the reviewed reports. The presentation of the data is clear and convincing. The statistical comparison between the 71 mines with NEPA reports and the 25 mines that were carefully reviewed for the observed impacts shows that, in general, the population of the 71 mines is well represented by the 25 mines subsample. The report has investigated well the appropriate parameters for AMD, leaching and exceedances in water chemistry that could impact ground and surface water, within the limitations of the available data.

The weakness of the report is the fact that the authors did not present a review of at least the federal legal requirements for the presentation of the EISs and EAs, which could have changed with time. It is my impression that the mining companies only present the data and analysis that they are legally required to present. At the end, it is not clear how much of the failure in predictions is due to an inadequate legal frame and how much is due to lack of good protocols for the investigations (e.g., predictive models, geochemical analysis, hydrological analysis, etc.). Another weakness is the comparison with drinking water standards. Mine water waste is not supposed to have drinking water quality, but when it is discharged into surface or groundwater, it should not produce a mixing that is above some standard. For surface waters, the standards for aquatic life are more appropriate than drinking water standards. In many cases, it is likely that surface and ground water have already had contaminants that have been released naturally from the rocks in the area, making the baseline chemistry already contaminated. A statistical comparison with the background or baseline data to see if there is a significant increase in the contaminant concentration after exploitation could be more appropriate (as it is done in the case of landfills). However, we have to recognize that the lack of data in surface and ground water prior to mine exploitation, probably made the authors decide on the used methodology. Another problem with the report is that it only considers the water quality near or at the mine. It did not look at the effects on the aquatic organisms or it did not mention if studies of such nature have been done for some mine sites.

b. Results and conclusions?

Within the methodology of investigation and its limitations, the results and conclusions presented by the authors are well supported. Even when the comparison of the water chemistry is made with respect to drinking water standards, the main objective of the report was to illustrate the percentage of mines that have or not adequately predicted the resulting water quality and/or exceedances, and when the mitigation efforts of the mine companies have been successful or not. In that sense, the reference concentrations used do not matter. What is important is the comparison between the predicted and observed values. The percentage of mine failures is alarming and should enlighten the regulatory agencies about the need for new and better regulations, and the need for better predictive tools.

Even though the report, in general, is well written and the conclusions are well supported, I was a little disappointed because the authors did not write a more extensive and complete analysis about why the companies fail in their predictions, even when some conclusions were stated in Section 8. It is clear in the report that the problem has two facets: 1) There are **regulatory holes,** such as the requirement of complete surface and groundwater studies at the watershed and groundwater basin levels, determination of the baseline surface and groundwater chemistry prior to exploitation, appropriate kinetic tests, appropriate selection of rock samples and sampling sites, pilot laboratory studies to determine the possible success of the mitigation alternatives, appropriate monitoring of the water quality at strategic points and wells to determine the level of pollution during the exploitation of the mine and after closure. Mining companies try to comply only with the regulatory requirements and usually do not do additional work that could even affect the possibility of success in the permit applications. 2) The second point is the fact that prediction tools (e.g., modeling programs that consider the complexity of AMD and leaching generation and their fate in the environment) are not efficient enough to make prediction, especially in the mitigation problem. This is probably related to the fact that no mines were found to have done laboratory tests or pilot studies to determine the possible success of the mitigation work.

One surprising result is that most failures are due to geochemical characterization (11/25). I have always thought that the lack of complete hydrogeological studies was, in most cases, one of the reasons for failure. These two factors should not be too difficult to improve with adequate regulations and supervision from government agencies. As indicated by the authors, "The case studies also demonstrate that inaccurate geochemical predictions often lead to lack of identification of adequate mitigation measures".

Christian Wolkersdorfer

a. Methodology?

The strength of the report is that it investigated a relatively large number of EISs; a task that was not done before for those types of mines, especially in such a detail. They provide a relatively large number of tables based on the data they reviewed (geology/mineralization; climate; hydrology; field and laboratory tests performed; constituents of concern identified; predictive models used; water quality impact potential; mitigation; potential water quality impacts; predicted water quality impacts; and discharge information) and also listed the prediction failures depending on various important parameters they identified. Those parameters include for example, distance to groundwater table and distance to surface water body. Because of the large amount of data and information provided, this report can be used to prevent future failures when predicting potential environmental impacts from large-scale mining operations. It is advantageous that they identified critical parameters, which often caused incomplete predictions and those identified weaknesses of prediction tools can be easily overcome in the future when using their report, as they state on page ES-12: "Results from this analysis can be used to make recommendations for improving both the policy and the scientific and engineering underpinnings of EISs."

The weakness of their methodology is that they only listed failures– except in Section 8 – without going into the details of each failure and giving detailed recommendations of how to avoid them in the future. In addition, they did not use statistical methods to support their results.

Furthermore, as they state on page ES-7, "baseline data were generally difficult to obtain," therefore, it is not clear if the elevated concentrations they are referring to are, in all cases, mining induced or pre-mining concentrations. This information should somehow have been mirrored in one of their numerous tables.

b. Results and conclusions?

The conclusions they draw, based on their above described methodology, do not use statistics to prove their findings or to demonstrate if the 25 case studies are representative for the all major hardrock mines in the U.S. For example, they just state that the 25 case studies used are representative for all 185 mines – but they do not present a table with statistical results. In addition, the authors failed to provide a time-dependent description of the failures they investigated. Mining, environmental requirements, and technology are constantly improving. That means that a mine that worked according to all legislative requirements in the 1970s, might not have been permitted in 2012.

From my perspective, if their information were analysed to identify the weaknesses of some methodologies and the advantages of other methodologies, this report might have been of great value for the mining industry. Section 8 fulfills this task only partially.

Especially Tables ES-5 to ES-9 might leave the impression that it is never possible to accurately predict post-mining environmental effects. Yet, they do not distinguish between "minor" exceedances and "major" exceedances, or they do not investigate if the past failure has been addressed by the mining industry. In addition, the tables give no indication if legislation changed after a major incident to prevent future incidents of that kind or if the permitting authorities are aware of potential failures and request more sound information today. Their conclusions and recommendations on page ES-15 are just the beginning of such a process.

Question 3. Are there important limitations or uncertainties associated with applying results from the Kuipers et al. 2006 report to the EPA assessment? If so, what are they?

David A. Atkins

The results of the report could inform any review of water quality prediction for mining projects, with emphasis on identifying if the sources of prediction error have been adequately addressed, including geochemical and hydrologic characterization and impact mitigation or site engineering design. The report also highlights that predictive modeling of natural systems is inherently difficult. However, models can offer insight into system design and performance even if they 'fail' to predict actual conditions. Therefore, it is critical that proper monitoring, regulatory oversight, and mitigation be in place, with multiple lines of contingency in the event of a failure.

Results of this report should be considered in a general sense when reviewing mining project predictive model results for the following reasons:

- Characterization and modeling methods have generally improved since the time when NEPA documents were prepared for the projects studied (primarily the 1990s) and since this report was prepared (2006). In addition, some standardization in approach (e.g., types and numbers of samples and testing methodology) has emerged.
- Models can never be expected to accurately predict complex natural systems and actual water quality will always be different than that predicted. The focus should be on whether a model has identified areas of concern such that proper mitigation can be designed and implemented if necessary. Model results should be used to guide project implementation and design.

Robert Kleinmann

I believe that the overall conclusions and results of the Kuipers et al. report are quite sound, though in a couple of cases, the case studies sometimes overemphasized the significance of certain environmental impacts. There are, of course, always uncertainties in such a study. The principal concern of this study is that the researchers looked at mines that had received permits and had operated over very different time periods, during which the state-of-the-art was rapidly changing. Their analysis did not look at this aspect, though it is clear that the authors recognized the potential importance of this aspect. Given that the state-of-the-art has continued to evolve since the report was published in 2006, it is reasonable to assume that most of the recommendations that the authors made in their report should indeed appear in the Pebble Mine environmental impact assessment, regardless of whether or not the authors will have read this report. The industry as a whole has evolved quite a bit during the last decade and mining permits and environmental impact assessments should reflect this evolution.

Dina L. Lopez

I think that the main conclusion of the report is the fact that mines with the potential to produce AMD and leaching of contaminants that have relatively shallow groundwater and surface water near or at the mine site are more susceptible to generate contamination problems. The uncertainty in this conclusion is relatively low and only produced by the fact that the sample considered only had 25 mines. EPA should take these results and conclusions under consideration, even when the authors have only the immediate impact to surface and groundwater resources and have not determined or mentioned the impacts to aquatic life. The report is a good contribution to the identification of potential problems and the need to improve our prediction tools and mitigation work before considering permits in areas that could be assigned as high risk according to the conclusions of the report. However, it should be noted that in addition to the potential water pollution environmental impact, other factors such as the long-term economic value of other activities and social and ecological aspects should be considered. Those impacts also have an economic value and often are underestimated, especially when the long-term effects are not considered.

Other minor points about the report:

1) It is not clear when the mining companies should get notices of violation and who should issue them in each case studied. For the mines that have received violation notices, the authors should mention the values in each case and the expected maximum values for the state or EPA regulations.

2) Why is NEPA not required by EPA for all the NPDES permits in many cases? The authors should indicate why, in each case when it was not required.

3) Distinction should be made between "accidental" problems and chronic problems. The "accidents" could be minimized with a good hydrogeological and climatic studies and good practices for handling the waste.

4) The production, movement, and deposition of sediments are also important for water quality. The report did not address the sediments generated by the mines and potential problems. Even if the final waters are neutral, the neutralization reactions produce a high load of sediments that also affect aquatic life.

5) This report could have been a lot easier to read if the authors added a few pages to include a map of the US with the different mines, and maps of each of the 25 mines that they studied in more detail (a few pages to add to an already long report).

Christian Wolkersdorfer

As described before, the report is a valuable document in regards to the past information gathered. The mining industry can use the information to improve the prediction of potential environmental impacts and to improve post-closure remediation and treatment methods.

Though the authors try to verify by means of tables that the 25 mines are representative for all the 183 major US hardrock mines, there is no statistical evidence that they are really representative. A nonparametric statistical evaluation would have proven if their approach can be used or not.

Yet, the conclusions drawn by the authors leave the feeling that current mining is not able to deal with the challenges of responsible mining and that the methods the mining industry are using are not able to predict future development. The mining industry invested a lot of effort to ensure that future potential environmental impacts can be predicted to a better degree (e.g. GARD Guide). All mining companies learn from their past experiences and improve mining operations. What the report lists are past experiences, which cannot be used as a general rule to predict the future development of the mining industry and its potential impacts. The mining industry constantly develops better prediction tools and treatment options.

The limitations of the report, therefore, are that they investigated the past and draw conclusions for the future. They do not use comprehensive statistical methods to prove that the 25 case studies presented are really representative for all mines they investigated. And if they are representative, they are only representative for existing mines, not for future mines that learn from their past. At no place in the report do the authors give proof that a) the 25 case studies are significantly representative for all existing and future mines, and b) that today's mining methods improved and take into account the evolution of science and technology.

In Section 8, they try to compile their findings, but again, there is no statistical evidence that the findings are significant for all mines. For example, they could have provided a table identifying the failures in relation to the production year of when the EIS was produced. Or they could have listed if a given incident initiated modifications in regulatory procedures, ensuring those incidents don't occur any more.

The whole report should have used a fuzzy logic approach, as the data they investigated are fuzzy in itself. Such fuzzy approaches exist and the report would have greatly valued if such an approach had been used. The information they provide is scattered throughout the report. There are a large number of tables, but a summary or a cross table, based on sound statistical methods, is missing.

There is no single summary table in the report. The large number of tables with just a little bit of information is confusing. The authors are very much stuck to the table structure they introduced in Table 4.2. A comprehensive table based on scientifically sound statistical methods for non-parametric data or fuzzy data would have been of great value. It would have been interesting to see, for example, if there is a dependency of the failures on the year when the EIS was compiled or the mine started operation. Or, it would have been interesting to see if a specific mining company or consulting company fails more often than others. In no case do the authors provide a degree of evidence that the failures will very likely also occur in a modern mining operation in a sensitive environment, knowing of the past failures. Their summary on page ES-15 is a good first example of what can be used by modern mining operators and engineering firms, to overcome the weaknesses Kuipers et al. 2006 identified.

Because of the lack of statistical proof that the core findings of their presentation (e.g., 25 case studies) are representative for all past and future mines, the value of this report for the EPA assessment is questionable. Yet, the EPA assessment could consider their summary on pages ES-15 and ES-16 to ensure a sound environmental mining operation at the proposed Pebble Mine.

Literature

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